Developing novel farming systems: effective use of nutrients from cover crops in intensive Organic Farming

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Abstract

On-farm nitrogen fixation is a driving force in organic agriculture. The efficiency with which this nitrogen is used can be increased by using alfalfa or grass-clover crops directly as fertilizer on other fields: cut-and-carry fertilizers. In two crops in two years, the use of several types of alfalfa and grass-clover as fertilizer is compared with the use of poultry manure and slurry. The nitrogen use efficiency at crop level is comparable or better for the cut-and-carry fertilizers as compared to the animal manures. The relative P and K content of these fertilizers comes closer to the crop demand than that of the poultry manure. Crop yields are comparable or better when using the alfalfa or grass-clover as fertilizer. It is concluded that the cut-and-carry fertilizers are a serious alternative for manure as part of an overall farm soil fertility strategy.

Introduction

The objective of this study was to address the issue of developing intensive cropping systems that facilitate more effective use of on-farm N-fixation. This was achieved by developing innovative “cut-and-carry” cropping systems based on perennial grass clover or alfalfa crops. Including these forage crops in arable cropping systems will enhance soil quality in general. In this manner nutrients accumulated by these deep-rooted crops can be used as soil amendment rather than being sold and shipped off the farm as forage. This is very desirable because the revenues from these crops are rather limited whereas the on-farm nutrient use efficiency with these crops, that feature very high dry matter and nutrient accumulation, can be appreciable.

Materials and methods

The experiments were located on a organic farm in the centre of the Netherlands (52°39’08 N ; 5°48’07 E; 3 m below sea level) on a well drained clay soil with 2.6% of organic matter, 280 mg P kg^{-1} (P-Al) and 46 mg K kg^{-1}.

During 2009 the use of freshly (1st cut of season) grass clover, alfalfa, and silaged alfalfa were compared with application of chicken manure as a nutrient source for fall-grown spinach. Alfalfa was cut in pieces of about 3 cm. All materials were being

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applied manually five weeks before the sowing of spinach and shallow (8 cm) incorporated. An additional treatment was included to evaluate the effect of applying materials later by incorporating alfalfa at ten days before sowing as well. Actual N application rates amounted to 0, 165, 200, 202, 267 and 271 kg N /ha for the control, late application of alfalfa, silaged alfalfa, chicken manure, grass clover, and alfalfa, respectively. There were four replicates of each treatment in a randomized field lay-out.

In 2010 the experiment was repeated in a potato crop using slightly adapted treatments. The treatments, again in four replicates, were zero application, freshly cut alfalfa, alfalfa silage early application, alfalfa silage late application, poultry manure and a mixture of cattle slurry with vinasse. Poultry and cattle slurry originated from organic sources, vinasse from sugar beet production. Alfalfa early application was realized when planting the potato seeds; the other applications took place three weeks later when the ridges were build. The N application rates were 125 kg for the alfalfa treatments and the poultry manure treatment, and 93 kg for the mixture of cattle slurry and vinasse.

Results

Regarding N-availability, it was observed that after soil incorporation the subsequent mineralization of plant material was very rapid and within 5 weeks between 27% (silaged alfalfa) and 38% (fresh partly-dried alfalfa) was readily available while for chicken manure this number staggered at 17%.

Fresh yield of spinach was the highest with the use of fresh cut grass clover and alfalfa, applied 5 weeks before sowing of the spinach (Fig. 1). Yield increased with soil mineral-N values at sowing time with maximum yields occurring at around 175 kg N/ha. Compared with chicken manure, use of alfalfa and grass clover applied 5 weeks before sowing increased N production efficiency by 32-44%. However, delaying application to 10 days before sowing did not result in an appreciable improvement of N production efficiency. Mineral removal rates amounted to 67-126 kg N, 13-17 kg P and 122-233 kg K per hectare.

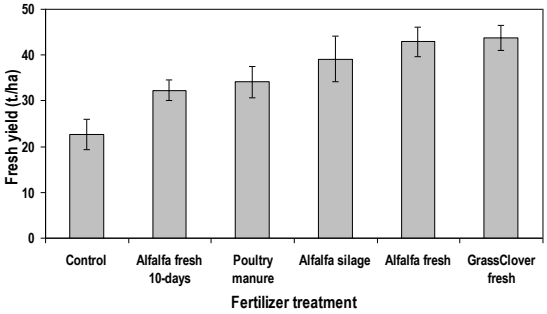

Figure 1: Fresh yield of spinach in different fertilizer treatments

The P and K content of the forage crops closely matched actual crop demands of spinach resulting in only relatively slightly positive nutrient balances (Table 1).

The P surplus of the poultry manure is very high. To assess the effects of treatments on crop performance we also calculated the apparent nitrogen recovery (ANR). This index calculates the additional nitrogen yield in comparison with the non-fertilized control per unit nitrogen present in the nutrient source.

Tab. 1: Mineral balance of phosphate and potassium and ANR for spinach in 2009.

	P*		K*		ANR*	
Spinach	(kg ha-1)		(kg ha-1)		(%)	
Control	-7	e	-31	c	-	
Alfalfa fresh 10 days	36	b	70	a	21	ab
Alfalfa silage	21	c	36	bc	23	a
Poultry manure	141	a	61	ab	15	b
Grass clover fresh	20	c	89	a	22	ab
Alfalfa 36 days	14	d	59	b	22	ab

*Significant for P < 5% after ANOVA

When the ridges were build in the 2010 potato experiment, soil N_{min} in the early alfalfa silage plots was on average 38 kg ha^{-1} higher than on the other plots. The marketable yield of the potatoes was in all treatments higher than in the control and the alfalfa treatments had the highest yields, but differences between the fertilized treatments were statistically insignificant. Nitrogen removal rates varied from 64 to 92 kg ha^{-1} .

The P content of forage crops closely matched actual crop demands of potatoes resulting in only relatively slightly positive nutrient balances (Table 2). For K all treatments except the Slurry/Vinasse show negative balances. The ANR is lower for the poultry manure.

Tab. 2 Mineral balance of phosphate and potassium and ANR for potato in 2010.

	P*	K*	ANR**	
Potato	(kg ha-1)	(kg ha-1)	(%)	
Control	-16	-139	-	
Alfalfa fresh	11	-83	20	b
Alfalfa silage early	2	-68	22	b
Alfalfa silage	3	-58	20	b
Poultry manure	132	-28	11	a
Slurry/vinasse	-10	26	18	b

* P and K based on measured input and default P and K content.

**Significant for P < 5% after ANOVA

Discussion and conclusions

The nitrogen out of alfalfa and grass-clover has a comparable or better ANR then nitrogen out of poultry manure or slurry/vinasse. At crop level the P balance was much better using alfalfa or grass-clover in both crops. Use of chicken manure resulted in a hyper-accumulation of phosphorus of 132 - 141 kg P ha^{-1}. The K balances are more ambivalent. This shows that cut-and-carry fertilizers such as fresh or silage alfalfa and grass-clover have a high potential as nitrogen fertilizer, meanwhile substantially reducing the risk of unbalanced P and K applications.

At farm level, the use of cut-and-carry fertilizers has consequences for the mineral balance. If a manure input from outside the farm is replaced by a farm-grown fertilizer, less phosphorous and potassium are brought into the farm to compensate the output of minerals by sold products. On the other hand, by selling a forage crop a lot of nutrients are sold and normally this will be compensated by purchasing manure. The overall effect on the mineral balance of introducing cut-and-carry fertilizers in a farming system will strongly depend on the starting situation and the choices made by the farmer. An economic evaluation study indicated that the cut-and-carry fertilizers are of interest with prices above 12 € per ton of cattle slurry (€3.50 kgN^{-1}).

Conclusions

It is concluded that a cut-and-carry fertilizer system facilitates an effective use of perennial leguminous forage crops for sustaining inherent soil fertility. Based on studies in spinach and potato it appears that use of freshly cut or silage materials from such crops will result in comparable yields while reducing the dependence of arable farms on external animal manures by more effectively closing nutrient cycles. It is expected that, with pending and more restrictive regulations for the use of animal manures and phosphates in the Netherlands, the cost of organic nutrient sources such as cattle slurry will increase. This will render the use of cut-and-carry fertilizer crops more cost-effective. Using this strategy will further reduce the fertilization cost of forage-based systems while minimizing the potential risk of nutrient depletion associated with exclusive use of green manure crops or hyper-accumulation of phosphate due to excessive use of chicken manure.

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